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LEVEL II

SUMMARY REPORT

(Tasks 5a and 5b)

AN/SQS-26 RELIABILITY AND SSI BEARING ACCURACY AS FUNCTIONS OF REDUNDANCY AND TOLERANCES (U)

Prepared for

The Bureau of Ships
Code 688E

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TRACOR, INC. 1701 Guadalupe St Austin 1, Texas

(15) Contract NObsr-91039
Project Serial Number SS041 001 (16) Task 8100

(9) SUMMARY REPORT,
(Tasks 5a and 5b)

(6) AN/SQS-26 RELIABILITY AND SSI BEARING ACCURACY AS FUNCTIONS OF REDUNDANCY AND TOLERANCES.

Prepared for

(14) TRACOR-64-122-C

The Bureau of Ships
Code 688E

(12) 12p.

This summary report contains short summaries of some work performed for the SOFIX Program management.

(11) 13 Feb 64

Prepared by:

B. T. Kemp

(10) G. T. Kemp

J. M. Young

Approved by:

E. A. Tucker
ASW Manager

A

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TRACOR, INC. 1701 Guadalupe St Austin 1, Texas

AN/SQS-26 RELIABILITY AND SSI BEARING ACCURACY AS FUNCTIONS OF REDUNDANCY AND TOLERANCES (U)

This summary report ~~for Tasks 5(a) and 5(b)~~ consists of a brief description of the work performed and the results obtained and is composed of abstracts of résumés of documents generated in response to these task statements. The task statements are repeated here for convenience:

Task 5(a). Determine the AN/SQS-26 system redundancy and its effect on reliability by statistical methods.

~~Task 5(b).~~ Perform bearing accuracy studies for AN/SQS-26 system from the transducer and dome through the equipment display.

Since many of the documents are applicable to both of the tasks, no effort has been made to separate them under the two task statements. The first three reports deal primarily with the effects of redundancy and component tolerances on AN/SQS-26 performance. The next four are concerned with various causes of SSI bearing error. The last five documents deal with the AN/SQS-26C specifications and the reliability requirements memorandum.

TRACOR, INC. 1701 Guadalupe St Austin I, Texas

1. "SOME REDUNDANCY EFFECTS ON AN/SQS-26 PERFORMANCE (U)" TRACOR, Inc. Technical Memorandum, 9 September 1963, Contract NObsr-89265, TRACOR Document No. 63-233-C (CONFIDENTIAL).

This technical memorandum presents the results obtained from beam pattern computations for arrays in which various percentages of transducer elements, power amplifiers or preamplifiers were assumed to be inoperative. Beam patterns for both transmit and receive in all modes of operation were computed for eight arrays in which the positions of the inoperative components listed above were randomly located within the array. For these cases, from 10% to 50% of the components were assumed to be inoperative. Beam patterns for only the transmit modes were computed for nine arrays in which one or more complete horizontal layers of the transducer (from 12.5 % to 37.5% of the components) were assumed to be inoperative. Beam patterns for all of the cases computed are included in the report.

These computations were made to determine the number of inoperative tranducer elements, power amplifiers or pre-amplifiers that would cause specified degradations in five sonar system performance parameters: (1) source level, (2) side lobe level, (3) receiving directivity index, (4) SSI bearing error, and (5) source level and receiving directivity index combined. Plots were presented showing changes in these quantities as a function of the percent of assumed inoperative components. Systematic SSI bearing error was indicated on plots of electrical phase difference vs. bearing angle for XN-2 phase compensation.

An analytical study of the effects of noise on SSI bearing error (for a single sample of signal and noise) was also included.

This technical memorandum was distributed as shown on the list attached to the forwarding letter.

2. "SOME COMPUTED EFFECTS OF ASSUMED INOPERATIVE TRANSDUCER STAVES ON BEAM FORMATION AND SSI PERFORMANCE IN THE AN/SQS-26 SONAR EQUIPMENT (U)," TRACOR, Inc. Technical Note, 29 January 1964, Contract NObsr-91039, TRACOR Document No. 63-285-C, (CONFIDENTIAL).

This technical note is a supplement to the TRACOR technical memorandum on redundancy (see Item 1). This investigation was made to determine the effects of inoperative post amplifiers, or transducer staves, on horizontal beam patterns and SSI bearing error. Computations were made for eleven arrays in which from six to twelve of the 24 staves were assumed to be inoperative. Only the receiving mode of operation was considered. In five of the arrays, six adjacent staves were assumed to be inoperative in various locations relative to the array center to simulate the effect on adjacent fixed horizontal beams.

It was found that:

(a) Randomly located inoperative staves produce much greater changes in side lobe level and receiving directivity index than a comparable number of inoperative elements.

(b) Six adjacent inoperative staves produce pronounced increases in side lobe level.

(c) No systematic SSI bearing error is caused by inoperative staves if the array is phased to a straight line, but the rms bearing error in the presence of noise increases as the S/N decreases.

This technical note was distributed as listed on the list attached to the forwarding letter.

3. "SOME COMPUTED EFFECTS OF PHASE AND AMPLITUDE TOLERANCES OF TRANSDUCER ELEMENTS AND PREAMPLIFIERS ON BEAM FORMATION AND SSI PERFORMANCE IN THE AN/SQS-26 SONAR EQUIPMENT (U)," TRACOR, Inc. Technical Memorandum, 23 September 1963, Contract NObsr-89265, TRACOR Document No. 63-242-C, (CONFIDENTIAL).

This study was conducted to determine the computed effects on horizontal receiving beam formation and SSI bearing error of phase and amplitude tolerances for transducer elements and preamplifiers for the AN/SQS-26C sonar equipment.

Computations were made for 38 all-elements-active arrays with combined tolerances on phase and amplitude ranging from $\pm 9^{\circ}$ to $\pm 30^{\circ}$ in phase, and from 0 db to ±10 db in amplitude. The variations on the response of each element (including the transducer element and preamplifier) were chosen randomly within the tolerances for that particular array.

These computations clearly indicated that the effects of random variations within the specified equipment tolerances of $\pm 9^{\circ}$ in phase and ±1.5 db in amplitude are not measurable in practice in regard to beam formation and SSI bearing error. Larger tolerances (up to $\pm 30^{\circ}$ in phase and ±10 db in amplitude) do show some effects on beam formation but are probably still acceptable with regard to SSI bearing error.

The results also indicate that the SSI bearing errors due to the largest tolerances assumed are comparable with those due to noise at signal-to-noise ratios used in target tracking (about 15 db). At lower S/N's, the error due to noise is of course much larger.

In addition to the 38 arrays discussed above, computations on four arrays were conducted in which it was assumed that the elements not only had large tolerances in phase and amplitude, but that some of the elements were completely inoperative. These computations showed more beam pattern effects and somewhat larger SSI bearing errors than the comparable array with all-elements-active.

Also included in this technical memorandum was an analytical study of the effects of phase tolerance only on SSI bearing error.

This technical memorandum was distributed as shown on the list attached to the forwarding letter.

4. "THE EFFECT OF ECHO LENGTH ON SSI BEARING ERROR IN THE PRESENCE OF NOISE (U)," TRACOR, Inc. Technical Note, 25 October 1963, Contract NObsr-91039, TRACOR Document No. 63-263-C, (CONFIDENTIAL).

This technical note extends the earlier analytical work on SSI bearing error due to noise (see Item 1 above) to consideration of several statistically independent observations. Since the number of statistically independent samples is proportional to echo length (and input bandwidth) and the standard deviation of the average of the values during an echo is inversely proportional to the square root of the number of samples, the RMS bearing error is smaller for longer echoes.

Plots of RMS bearing error vs. signal-to-noise ratio for various ping lengths are provided. The effect of echo lengthening by finite-size targets in considered.

This technical note was distributed as shown on the list attached to the forwarding letter.

5. "HORIZONTAL BEAM FORMING PHASE DELAYS (U)," TRACOR, Inc. Technical Note, 21 October 1963, Contract NObsr-89265, TRACOR Document No. 63-259-C, (CONFIDENTIAL).

Computation of SSI bearing errors for cases in which several adjacent staves were assumed to be inoperative (see Item 2 above) indicated inordinately large bearing errors. This raised questions concerning the array phase compensation values being used in the computations. The values used were obtained from USNUSL and are those used in the actual AN/SQS-26, (XN-2) equipment. Phase delays required to phase the array to a straight line were calculated and were significantly different from the XN-2 values. A horizontal receiving beam pattern was computed for each set of phase delays in order to determine the pattern effects. Computations using the set of straight-line phase delays produced a pattern having a narrower main beam, lower side lobes and greater receiving directivity index than was obtained using the XN-2 phase delays.

This distribution list for this document was:

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6. "SOME COMPUTED EFFECTS OF DOME SKIN AND TEMPERATURE DIFFERENTIAL ON OPERATION OF THE AN/SQS-26 SONAR EQUIPMENT (U)," TRACOR, Inc. Technical Note, 4 October 1963, Contract NObsr-91039, TRACOR Document No. 63-248-C, (CONFIDENTIAL).

A limited analytical investigation was conducted to estimate the SSI bearing error in the AN/SQS-26 sonar equipment resulting from phase shifts (incident wave distortion) caused by (a) passage of the incident signal through the dome skin and (b) refraction resulting from a temperature differential between the water in the dome and the surrounding sea water.

In the interest of obtaining timely results, the first approach was to use a two-dimensional model and compute phase shifts and bearing errors, neglecting the effect of vertical curvature of the dome. SSI bearing errors were calculated for relative bearings of 30°, 45° and 60° for a temperature differential of $10^{\circ}F$ between the inside and outside of the dome.

Subsequently, an approach using a three-dimensional model was used to obtain more realistic values of SSI bearing error for the AN/SQS-26 equipment. In this case, the phase shift at each transducer element caused by the dome skin and a $10^{\circ}F$ temperature differential was determined. SSI bearing errors were computed at relative bearings of 30° and 45° at 0° depression angle, and for 45° bearing at 30° depression angle. The maximum computed bearing error was 0.12° for the 45° bearing 0° depression case, which is only about half the maximum error computed in the two-dimensional study. An immediate interpretation of this difference is that the bulbous dome of the AN/SQS-26 produces phase distortion in the vertical plane which, in the stave summing process, provides a smoothing effect. This smoothing actually reduces the SSI bearing error from that for a straight sided dome, of the type used

on many other sonar equipments.

The distribution for this technical note was as shown on the list attached to the forwarding letter.

7. "EXCERPTS FROM AN/SQS-26C SPECS," 16 September 1963, (CONFIDENTIAL).

A one-page (11" x 25") résumé of salient information concerning the AN/SQS-26C was made in which the pertinent features of each operational mode were listed in columns. The information collected on this data sheet was obtained from Contract Specification SHIPS-D-4511, 1 July 1963. This sheet was prepared for internal reference only in connection with preparation of Bureau of Ships Memo, Serial 688E-043 (see Item 10 below); however, BuShips, Code 688E was provided with two copies.

8. Letter to Bureau of Ships, Code 688E, regarding AN/SQS-26C Specification SHIPS-D-4511, 10 April 1963, (UNCLASSIFIED).

AN/SQS-26C specification SHIPS-D-4511 was examined in detail; each paragraph or specification was placed in one (or more) of the following categories:

(1) Specifications adequate for reliable equipment performance

(2) Specifications where reliability depends on specific design

(3) Specifications which should be studied further

(4) Insufficient information on hand

Some items falling in category (3) were studied further from a reliability standpoint and the results reported to BuShips, Code 688E. Study of items in category (3) concerning signal processing is being continued.

This letter received no other distribution.

9. "BLOCK DIAGRAM OF AN/SQS-26C, TRACOR VERSION," latest revision 12 November 1963, (CONFIDENTIAL).

This is an unofficial working drawing for use in preparation of Bureau of Ships Reliability Memo, Serial 688E-043, 6 June 1963. This block diagram was prepared from information contained in SHIPS-D-4511 and AN/SQS-26 Factory Lesson Guide Information Sheet 37-1 on the SSI Display. BuShips, Code 688E was provided with copies.

10. "RELIABILITY REQUIREMENTS FOR AN/SQS-26C SONAR EQUIPMENT (U)," Bureau of Ships Memo, Serial 688E-043 of 6 June 1963, Prepared by TRACOR, Inc., 20 December 1963, TRACOR Document No. 63-267-C, (CONFIDENTIAL).

This memorandum establishes some specific reliability requirements for the AN/SQS-26C sonar equipment as specified in Bureau of Ships Contract Specification SHIPS-D-4511 of 1 July 1963. The reliability requirements and measurement procedures set forth in this memorandum are to be used in conducting sonar equipment factory reliability tests. The tests are developed so as to remove variability of operator performance.

In this memorandum, criteria are established for determining the occurrence of a "mode failure" in terms of performance

degradation. A reliability test schedule is formulated and minimum reliability requirements (MTBF's) are tabulated for the various modes of operation.

The memorandum received the following distribution:

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